RELATIONSHIP BETWEEN DRYLAND COTTON YIELDS AND WEATHER PARAMETERS ON THE SOUTHERN HIGH PLAINS

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Abstract

Lack of an adequate water supply throughout the growing season is considered to be the major limiting factor to dryland cotton yields on the Texas Southern High Plains. Over the past 25 years, yields have had large year to year variation but the trend has been essentially a static yield. We gathered daily rainfall and temperature data from NOAA for the 1968 - 1992 period for each county in the Southern High Plains. Rainfall was developed to reflect stored water, growing season, critical growth periods and monthly supplies. Temperature data were used to develop heat units, high and low temperature thresholds. Regression analysis was performed in an effort to determine the extent to which these weather parameters control dryland cotton production, or, more importantly, to determine how much influence the individual producer is able to exert upon lint yield. Multiple regression revealed that in most cases less than 50% of the yield variation can be explained by a combination of weather factors. The other 50% of the yield variation is subject to management.

Introduction

The southern High Plains of Texas is the largest contiguous cotton production region in the U.S. with over 1.5 million hectares planted annually. The region is classified as semi-arid with annual rainfall of 450 millimeters and a precipitation: evapotranspiration ratio of less than 0.25. Over 65% of the annual rainfall occurs during the summer growing season; however, the evaporative demand often exceeds 12 mm/day. Therefore water supply during the growing season is considered to be the major constraint to crop production. About half of the total cotton acreage is irrigated (supplemental) with the other half totally dependent on rainfall. Water stress is the single most critical factor limiting cotton yields in the area. In general, steady and moderately moist conditions are more conducive to crop growth than erratically alternating periods of wet and dry conditions (Hobbs,1980). Therefore evaluation of annual or even growing season rainfall does not provide an accurate picture of the water supply to a growing crop and the resultant yield.

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Our purpose in this study was to determine the relationship between the water supply and evaporative demand and dryland cotton yields. If dryland yields are highly correlated with various weather components, then there is little that can be done to improve yields. However if a low correlation or an erratic relationship exists, then we have the opportunity to modify crop genetics or management systems to utilize the rainfall more effectively.

Materials And Methods

Historical (1968 - 1992) daily weather data were obtained from NOAA for seventeen counties on the SHP. Precipitation was separated into a variety of categories: annual, monthly, winter (Nov. - April), growing season (May - Oct.) and rainfall occurring during critical stages of growth such as vegetative, early fruiting and late fruiting periods. Two temperature parameters were also analyzed: mean daily temperature and daily minimum temperature, both taken during the growing season. Initially these rainfall and temperature categories were regressed on an individual basis against annual county yields and average regional dryland cotton yields. Finally, a stepwise regression technique was employed using a group of independent parameters.

Comprehensive weather data were collected from research sites in Terry County and Lubbock County with automated weather stations. Data included hourly temperatures, relative humidity, radiation, rainfall, soil temperatures and wind speed. A widely used potential evapotranspiration (ETp) equation, (Penman, 1948), was used to estimate daily ETp from temperature, radiation, relative humidity and wind measurements. Using these ETp data as a baseline, the Blaney-Criddle ETp equation, based only on mean daily temperature and estimated winds and humidities, was adjusted to obtain accurate ETp data for each county on the SHP. Available moisture (daily rainfall) is compared with ETa, that is, the calculated ETp multiplied by a coefficient based on the stage of growth. This water available/water demand number was coupled with a temperature parameter to determine if the dryland cotton plant is under a stress condition. If there is a greater water demand than water available, and/or daily mean temperature is greater than a predetermined critical temperature, the cotton plant is considered "stressed".

Results and Discussion

One of the strongest individual relationships between rainfall and dryland cotton yield found was that between yield and winter rainfall (figure 1). Rainfall accumulated during the winter is positively associated with lint yield, with an r^2 of 0.45. Simple linear regressionrevealed that for every millimeter of rain received between November 1 and April 30 the SHP producer may expect an increase in yield of over 0.5 kg/ha. Though not as important, rainfall accumulated during the early reproductive period, June 15 -

July 14, was also associated with yield increase. A strong negative relationship was observed between September rainfall and lint yield (figure 2). For every millimeter of rain received in September, a producer could expect a decrease in yield of over 0.5 kg/ha. Rain in September favors vegetative regrowth over continued fruit development reducing potential yield.

Another negative relationship was observed between lint yield and the number of days when the average daily temperature exceeded 26^{O} C. The response was not as strong with the maximum temperature as it was with the mean daily temperature suggesting that warm nights are just as damaging as are hot days to dryland cotton production. Combining this daily temperature limitation with daily water available/ET demand determines whether or not the cotton plant was under a stress condition. When mean daily temperature is less than 26^{O}C and there is water available to meet ET demand, the plant is considered stress-free. Regressing the number of stress-free days against dryland lint yield shows a marginal correlation, with an r^2 of 0.25 (figure 3).

Multiple regression procedures were run for each of the 17 counties individually, groups of counties according to soil type and for the region as a whole. A more select set of variables was used in the multiple regression equations due to inter-dependent among the original set. Table 1 lists the variables used for the regression studies.

In the majority of the counties, winter rainfall remains the most important variable, often providing the producer with over 20 pounds of lint for each inch of precipitation received from November through April. In some counties, rainfall received during the previous September and October contributed to an increase in dryland cotton yield, while in other counties May and July rainfall was much more significant.

For many counties results from stepwise analysis revealed more weather factors which contributed in a negative manner than in those contributing positively towards lint production. Extreme temperatures - both high daily mean temperatures and daily low temperatures - were revealed to reduce dryland yield. However, the most significant and consistent variables negatively associated with dryland cotton production were September and June rainfall. While September rainfall favors vegetative regrowth, June rainfall has been linked to retarded seedling development due to intense thunderstorms, hail and wind, soil crusting and disease (Staggenborg, 1994).

For the seventeen county region, multiple regression correlation coefficients averaged just under 50%. The lack of a strong positive relationship between rainfall and lint yield does not mean that water stress is not the major limiting factor. However, the lack of a strong relationship does offer hope. If less than 50% of the yield variability under dryland conditions is due to factors out of our control (weather) then at least 50% of the variability may be subject to our control. We believe that management systems can be developed and implemented which will reduce the risk of severe stress when the rainfall is inadequate to meet the evaporative demand and that practices can be used to take advantage of the rainfall when it does occur.

References

1. Staggenborg, Scott. 1994. Maximizing cotton and sorghum yields and water use efficiency by optimizing plant density. Ph. D. Dissertation. Texas Tech Univ. Lubbock, TX.

Table 1: Rainfall and temperature categories used in both county and regional multiple regression analysis.

Annual minus September and October Rainfall
Previous September and October Rainfall
Winter (November - April) Rainfall
Crop Year (October 1 - September 30) Rainfall
May Rainfall
June Rainfall
July Rainfall
August Rainfall
September Rainfall
October Rainfall
Days with daily average temperature greater than 26^{O}C
Days with daily low temperatures below 16^{O}C

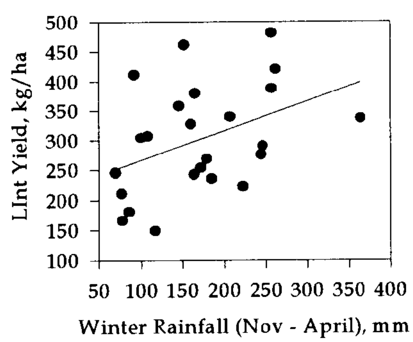

Figure 1. Winter rainfall averaged over 17 counties on the Texas Southern High Plains, 1969 - 1992.

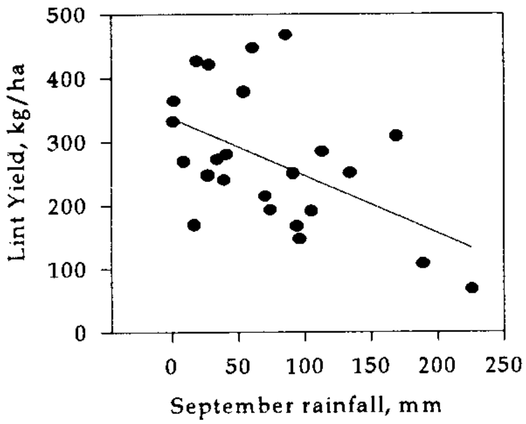

Figure 2. September rainfall for Terry county, 1968 - 1992.

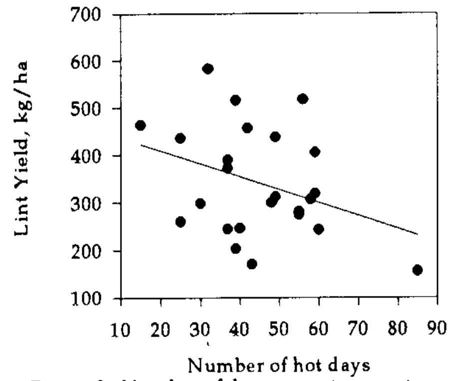

Figure 3. Number of days mean temperature exceeded 26^{O}C in Lubbock county, Texas.